Lysimeter – Whole Tree ET Response to Mild and Moderate Water Stress

Project No.: **15-HORT22-Shackel**

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Objective:

The long term objective of this research is to quantify the effect of water stress on the physiology and ET of almond orchards, and to develop a physiologically-based model of this relation that can be used to predict the water savings associated with practices such as hull split RDI. The goal for 2015 was to achieve good growth in the orchard, and to achieve as uniform a growth as possible between the tree in the lysimeter and the trees in the rest of the block. Another goal was to compare the measured ET of the tree in the lysimeter to published models for the ET of young trees (Johnson et al, 2004, Wang et al., 2007).

Interpretive Summary:

This was the first year of growth for the lysimeter almond project, and all trees, including the lysimeter tree, grew well. Observed Kc values in this first year were overall consistent with predictions from a previously published young tree ET model developed for peaches (Johnson et al, 2004), but both over- and underestimates of Kc using this model occurred. The model and the observed data both indicated that about 25% of ETc could be attributed to direct evaporation from the soil surface. Seasonal ETc was significantly underestimated by a more recently published simplified model (Wang et al, 2007). Despite irrigation to match the measured ETc, SWP values were typically 4 to 5 bars below the non-stressed almond baseline for most of the season, and applying excess irrigation to individual trees in the block using full cover microsprinklers, did not result in an increase in SWP to baseline values. This may indicate that there is a soil related factor other than water content at this site which may limit root water uptake, but this did not prevent the trees from growing well in this first year.

Materials and Methods:

A 3.5 acre lysimeter site (N36.5981 W119.5132) at the Kearney Agricultural Research and Extension center (KARE), previously used for grapevines (Johnson et al, 2005) was prepared and planted to almonds on 2/3/15. The orchard is planted at 4 x 6.5 m triangular spacing, with

50% Nonpareil, 25% Wood Colony, and 25% Monterey. The irrigation system for the first year is a single line drip system with one 8 l/h emitter per tree, and this will be expanded to a double line system with additional emitters as the trees develop. The weighing lysimeter was serviced, upgraded to directly measure drainage, periodically calibrated, and a cell modem was installed in the datalogger to allow for reliable remote access. Irrigation was managed based on regular SWP measurements of the lysimeter tree and a selection of 17 additional trees in the block, as well as by close monitoring of the lysimeter measured ET. Irrigation was applied as needed by remotely connecting to the lysimeter datalogger and operating the irrigation valves (one for the Nonpareil rows and one for the pollinizer rows) electronically. Midsummer irrigation frequency was typically twice weekly at about 0.15"/irrigation, applied overnight.

Results and Discussion:

Figure 1. Photograph of the lysimeter tree on August 26, 2015.

Leafout was approximately March 10, 2015, and the tree in the lysimeter, as well as those in the rest of the orchard, grew relatively vigorously throughout the year (**Figure 1**). A key factor in the peach ET model proposed by Johnson et al (2004) is the measurement of the % of land area shaded by the canopy at noon, and for young trees this can be difficult to measure directly. Johnson proposed a relatively simple method of measuring tree dimensions (height, and canopy N/S and E/W spread), and a number of measurements of these values were taken periodically during 2015. Among the more direct alternative methods is to take a photograph of the tree near noon (similar to **Figure 1**) and use image analysis to calculate the area of ground shaded, although correcting for the angle of perspective in this method can also introduce uncertainty. This method was also used occasionally in 2015 to compare with Johnsons method. To use Johnsons method, the date and the latitude of the site must also be recorded, because the angle of the sun at noon together with the tree dimensions will determine the % shaded area. Based on Johnson's method using tree dimensions, the percent shaded area increased from about 2% in April to about 20% in November in 2015 (**Figure 2**). It is important to note that the rapid increase from September to November was almost entirely due to the changing noon angle of the sun, rather than a rapid increase in the growth of the tree. For instance, tree height growth was most rapid in May, but had stopped by October 1, 2015. Johnson's simplified method based on tree dimensions did not agree well with photographically measured shaded area, particularly in the early part of the season (**Figure 2**). This may be because Johnson's method was developed for peach trees, which have larger leaves and which are also pruned and trained differently than almonds (the almond trees of this experiment were not pruned after planting). Both methods however indicated that, as expected, the % shaded area for young trees is very low for most of the season (on the order of 5%), but further analysis will be needed to determine which method is more appropriate for young almond trees.

As expected from the low % shaded area for young trees, both the lysimeter data as well as the Johnson model exhibited large increases in Kc following rain (**Figure 3**) as a result of direct evaporation (E) from the soil surface. Modeled and observed Kc values were compared for rain- and irrigation-free days from May through September, and while both exhibited the same overall range (somewhat below 0.1 to somewhat above 0.2), the modeled values systematically overestimated Kc in June and underestimated Kc in August/September (**Figure 4**). It should be noted however, that these model values are based on % shaded area estimated from tree dimensions, and that using the substantially lower photographically measured % shaded area values (**Figure 2**) would have led to better agreement in June but a larger difference in August/September. Johnson's model calculates ET as the sum of three separate portions: 1) tree transpiration (T), 2) evaporation from the soil area wetted by irrigation (E_W), and 3) evaporation from the non-wetted soil area (E_{NW}). If the soil has not been wetted recently by rain, E_{NW} becomes negligible. When soil evaporation is eliminated by covering the lysimeter surface, the lysimeter measured Kc can be directly compared to the tree transpiration portion of Johnson's model. For 3 days in mid-July and 2 days in mid-August, both measured and modeled values showed that a reduction in Kc of about 0.05 occurred when the soil was covered (**Figure 4**), indicating that soil evaporation represented a substantial fraction (about 25%) of ET for these young trees. In mid-July, when the modeled and measured Kc values were in good agreement, the measured average tree transpiration and the modeled value corresponding to this portion were also in good agreement, but by mid-August, the measured tree transpiration was higher than the corresponding portion in the model, parallel to the difference in overall Kc (**Figure 4**). Taken together, these comparisons indicate that improvements may be required in the tree transpiration portion, but not the soil evaporation portion of Johnson's model. This may become more apparent as the trees grow and shade a progressively larger fraction of the soil surface, reducing the relative importance of the soil evaporation portion of ETc. Because the model both over- and under-estimated Kc over time (**Figure 4**), there was good agreement (within about 5%) in the cumulative ETc for modeled and observed values over the May through September period (**Figure 5**). The Wang et al. (2007) model was in reasonable agreement with the observed values until mid-July (**Figure 5**), but by the end of September had underestimated ETc by about 40%. This underestimate may have been due the fact that the Wang model is only based on one value for the % shaded area at midsummer, whereas vigorously growing trees may substantially exceed this midsummer value as the season progresses.

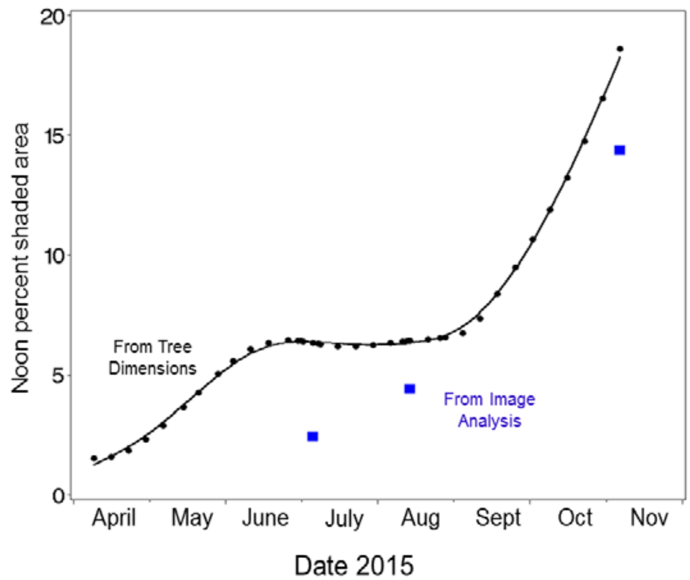

Figure 2. Percent shaded area for the lysimeter tree in 2015, calculated either using tree dimensions (dots) or based on image analysis using photographs (squares).

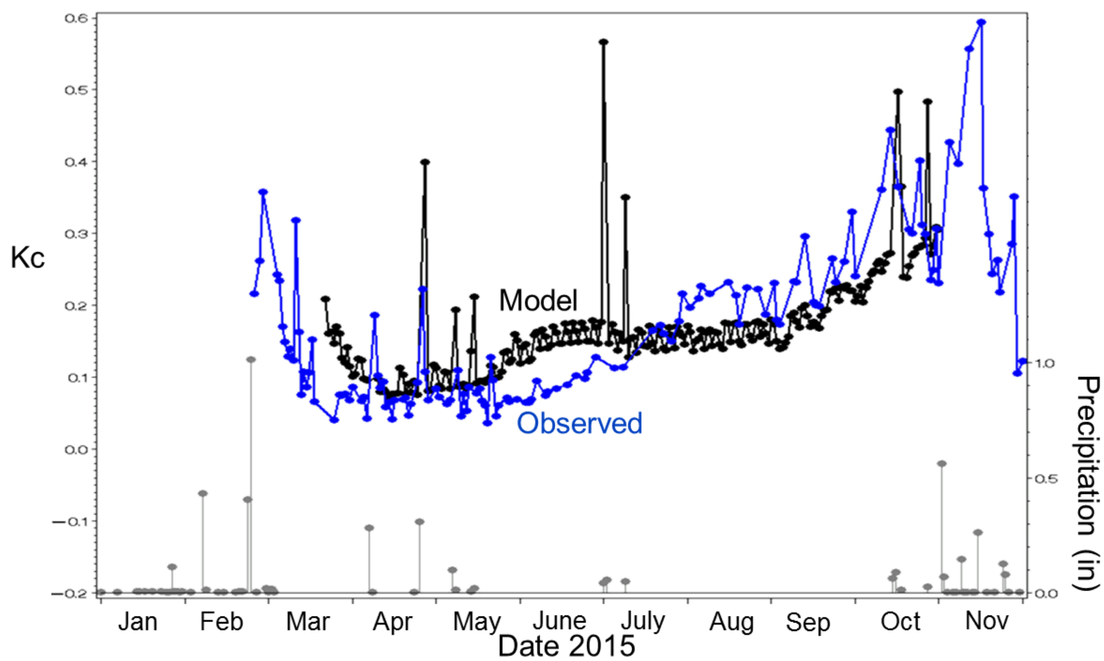

Figure 3. Seasonal pattern of modeled and observed crop coefficient (Kc, left axis) for the first year of almond tree growth (2015). Modeled values are based on the shaded area from tree dimensions shown in **Figure 1**. Rain events are also shown as vertical lines terminating with a dot at the quantity of rain (inches per day, right axis).

Immediately after planting, trees were basin irrigated, but despite good soil moisture conditions from rains in January/February, the SWP of the dormant trees was found to be surprisingly low (around -20 bars) in early February (**Figure 6**). By late February/early March, SWP had substantially recovered, but by mid-March (shortly after leafout) SWP had declined to about -15 bars in both the lysimeter tree and the rest of the trees in the block (**Figure 6**). Irrigation was started in mid-March, but appeared to have no influence on SWP, and the only times that SWP was close to baseline was following rain events in March, May, and June/July (**Figure 6**). It was surprising that for most of the summer, trees did not exhibit values close to the baseline, despite being irrigated to match ET, and a set of trees was selected to test whether a full - coverage microsprinkler irrigation with excess water would result in baseline SWP values. Prior to applying additional water, the set of excess irrigated trees and the nearby control trees had essentially the same SWP, and were typically about 5 bars below baseline (**Figure 7**). Following the application of additional water, both treated and control trees continued to exhibit the same SWP values, only approaching the baseline SWP late in the season (**Figure 7**). The reason why excess irrigation of the entire root zone did not result in baseline SWP values is not clear, but could indicate that for some reason other than soil water content, the soil conditions were not as favorable for root water uptake at this site compared to other sites, at least for first year trees. This, however, did not prevent the trees from reaching an acceptable size by the end of the season

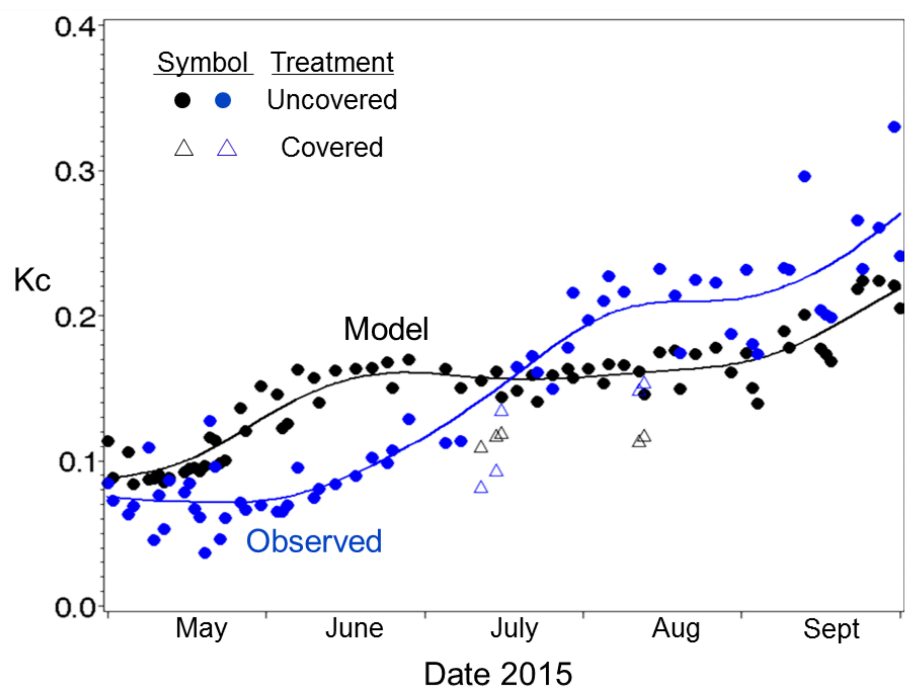

Figure 4. Detail of modeled and observed daily crop coefficient (Kc) for rain- and irrigation-free days from May through September, 2015, as in **Figure 3**. Dots represent daily values and lines are smoothed splines fit to the data. Also shown as separate symbols are days when the surface of the lysimeter was covered with a tarp to prevent soil evaporation. Observed Kc's on these days are shown as blue triangles, and the model values corresponding only to tree transpiration on the same days are shown as black triangles.

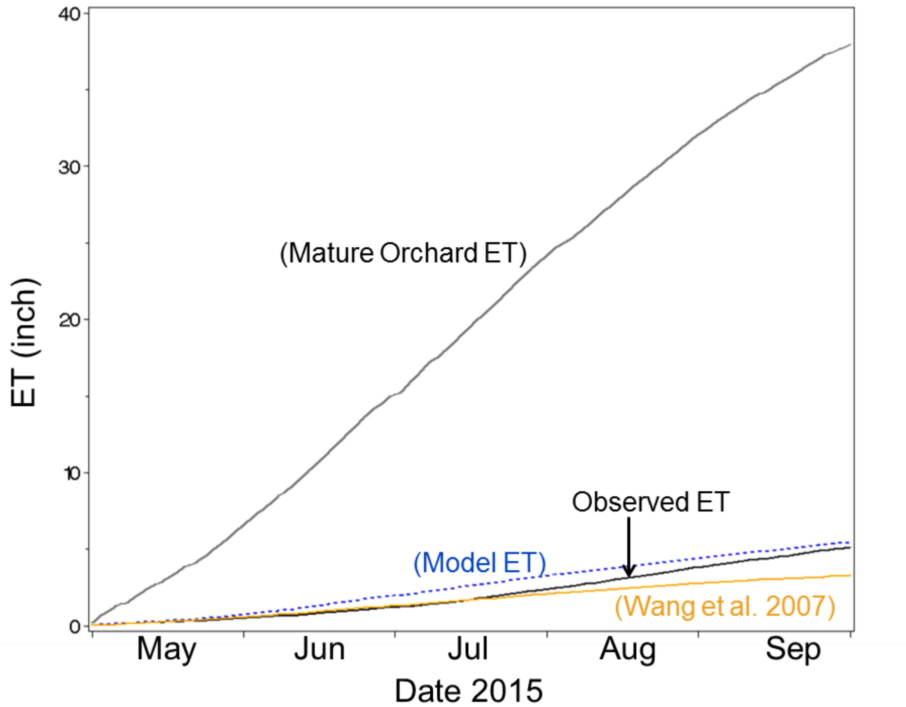

Figure 5. Cumulative evapotranspiration (ET) for the May-September, 2015 period, calculated for a mature almond canopy, compared to the modeled and observed ET (based on the Kc's in **Figure 4**). Also shown for reference is an alternative approach for calculating ET from Wang et al., (2007), based only on requiring a midsummer value for % shaded area.

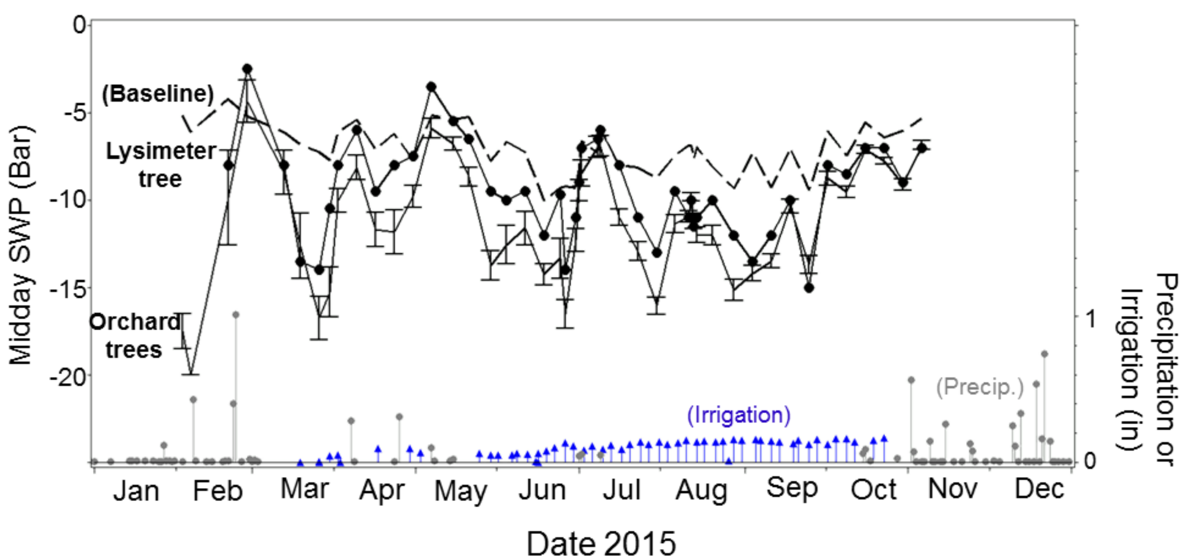

Figure 6. Midday stem water potential (left axis) predicted for non-stressed almonds (baseline), and the values observed for the lysimeter tree (dots) as well as the average (±2SE) for the rest of the monitored trees in the lysimeter orchard (N=17). Also shown are daily values of rain (precipitation) as in **Figure 3**, and irrigation events shown as vertical lines terminating with a triangle at the quantity of irrigation applied in inches (right axis).

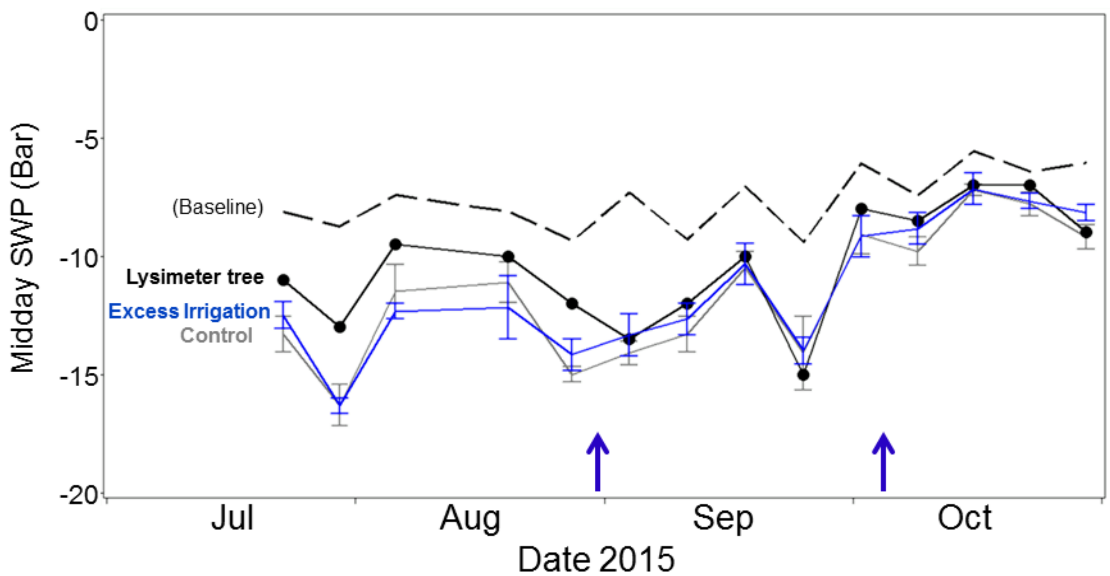

Figure 7. Detail of midday stem water potential measurements from mid-July through October calculated for the baseline and measured on the lysimeter tree (as in **Figure 6**), and for the average (±2SE) of three trees which were excessively irrigated by applying over 4" of water using a full coverage, individual tree microsprinkler system, on the dates indicated by the upward arrows. Also shown are the average (±2SE) of five nearby control trees that received the same twice weekly drip irrigations as the lysimeter tree and the rest of the block.

Research Effort Recent Publications:

None.

References Cited:

Johnson SJ, Ayars JE, Hsiao, T. 2004. Improving a model for predicting peach tree evapotranspiration. ACTA HORT 664: 341-346.

Wang J, Sammis TW, Andales AA, Simmons LJ, Gutschick VP, Miller DR. 2007. Crop coefficients of open-canopy pecan orchards. Agric. Water Manage. 88:253-262.